Final Exam: Introduction to Vehicle-2-X: Communication and Control (Microcredit course #1)

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1. What is the relationship between the power consumption of a vehicle to overcome the aerodynamic drag and the vehicle velocity?

Answer: The power to overcome the aerodynamic drag is proportional to the cube of the relative velocity of the vehicle to air. $\mathbf{P} = \frac{1}{2}\boldsymbol{\rho_{air} C_d A v_{rel}^3}$

2. What are the sources of rolling resistance of a vehicle? And how does the vehicle weight affect the rolling resistance?

Answer: Rolling resistance mainly comes from the deformation of tire (which is ultimately converted to heat), and also from the work done to circulate the air around the tire and tire slippage on the ground. The rolling resistance is proportional to weight. More specifically, proportional to the perpendicular component of the slope. $\boldsymbol{F_r(\alpha) = C_{rr} m_{tot} g \cdot \cos(\alpha)}$

3. How does the tire pressure affect the rolling resistance?

Answer: Low tire pressure results in more deformation, and hence higher rolling resistance.

4. What does it mean that a road has a slope of 100%?

Answer: The slope of a road is usually defined as the tangent value of the slope angle. So, the slope of 100% would mean $\boldsymbol{tan(\alpha) = 1}$**, and hence 45 degrees.**

5. The following equation describes the relationship between engine torque and angular velocity. $J^* \dot{\omega}_e = T_{net}(\dot{m}_a, \omega_e) - T_L$, where $\dot{\omega}_e$ is the angular velocity of the engine crankshaft, T_{net} is the net combustion torque, and T_L is the load torque which takes rolling resistance, braking torque and aerodynamic drag of a vehicle into account. What does J^* mean? What does $\dot{m}_a$ mean and how is it controlled?

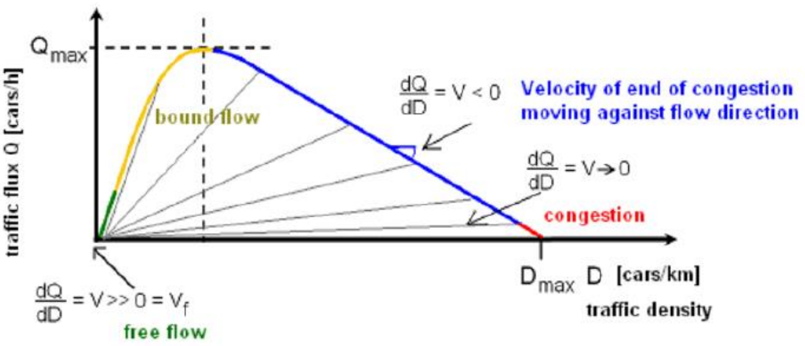
Answer: $\boldsymbol{J^*}$ **is the effective inertia reflected on the engine side.** $\boldsymbol{\dot{m}_a}$ **is the mass airflow "rate" (because of the dot) in engine manifold.**

6. What does Q=DV mean? What would be the units of Q, D, and V?

Answer: This is the equation which describes the relationship between the traffic flux Q (cars/h), the traffic density D (cars/km), and the velocity of traffic V (km/h).

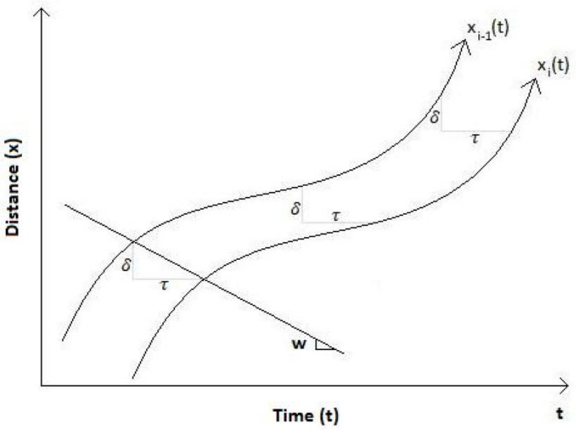
7. Could you draw the flow-density graph of the macroscopic traffic model? What does each section mean? What does the apex point and the intersection with the x axis mean?

Answer: Leftmost section denotes the free flow section, where vehicles can move at desired speeds. Center section denotes the bounded flow, where the vehicles with interact with each other. There is an apex point in the bounded flow section, which denotes the maximum capacity of a road. And then the rightmost section comes the congestion section near the jam density.



8. Could you explain Newton's car following model on a time-space diagram using the terms δ and τ? (Specify on graph δ and τ should be). Could you write the equation describing the relationship between δ, τ, space gap (s_A) and velocity ((v_A)? What are the names of δ and τ?

Answer: δ and τ are minimum space gap and minimum time gap (or headway or separation). The relationship is described by the equation $s_A = v_A\tau + \delta$



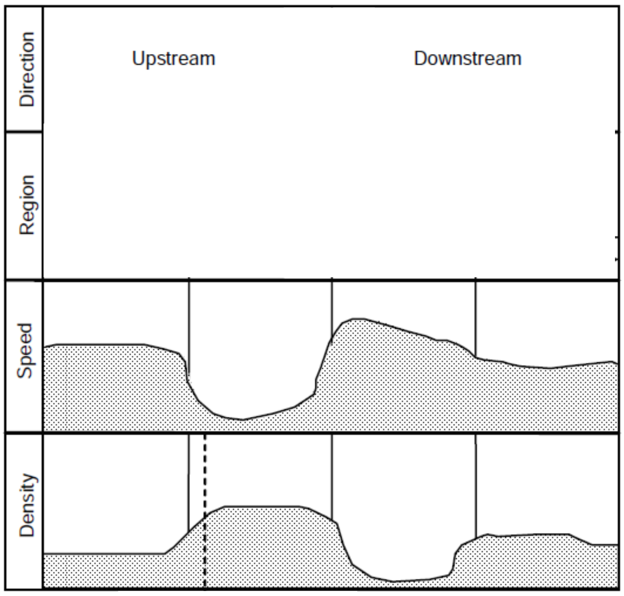
9. Can name a few things about shortcomings of video detection systems (camera) for traffic?

Answer: Sun glint is problematic during sunrise/sunset when the camera is positioned in the east/west direction. Large vehicles project/mask image to adjacent lanes. Shadows and reflections from wet pavements may reduce the accuracy of detection. It requires street lighting when detecting at night.

10. Can you describe how the induction loop detector works and what information (starting from the presence of a vehicle) it can gather? How can inductive loops measure speed?

Answer: Induction loop detectors detect the presence of metal using electromagnetic induction. It installs a loop under the road pavement, induces the electrical current in the loop and senses perturbations in the magnetic field it generates. They can detect presence of a vehicle, count the number of vehicles, lane occupancy, vehicle speed, and also vehicles class by counting the number of axles. Speed can be measured by setting up "speed-trap configuration". You install induction two loop detectors with a known distance.

11. The following is data from an automatic incident detection system on a highway. Can you find out where the incident has happened? Why do you think so? Vehicles are driving from upstream to downstream.



Answer: The incident happened in the middle (between the second and the third region). This can be observed by the reduced traffic speed and increased density, which means a traffic jam in the upstream direction of the incident. After the incident, (downstream direction) there is free flow where the speed is high and density is low.

12. How does LIDAR sensors work and what are the shortcomings (under which circumstances do they perform bad)? How would you compare with Radar?

Answer: LIDAR illuminates detection zones with laser in the near-infrared region and detects the portion of energy scattered back to the sensor. Laser beams are projected at different angles and scanned across a rotating mirror. Compared to radar, it performs bad under heavy fog, snow and in presence of foliage. But LIDAR has much higher resolution than radar.

13. What are the types of losses in signal strength in wireless communications?

Answer: There is propagation loss and attenuation loss. There is also connector loss and antenna loss. Propagation loss is due to spreading out of RF energy as the signal dissipates (inversely proportional to the square of distance). Attenuation loss is due to propagation through material other than air walls (obstacles like door, etc).

14. What is the relationship between transmission rate and transmission range when the transmission power is constant? Could you describe using the term "energy per symbol"?

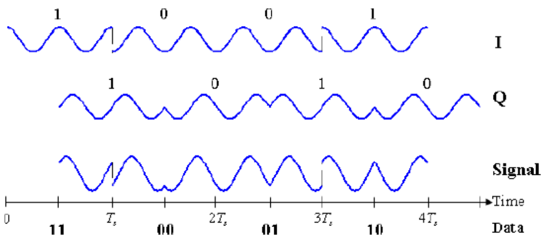
Answer: Transmission rate is lower as the transmission range increases, and vice versa. This is because energy per symbol is higher when the transmission rate is lower, which makes it easier to detect from the receiver side.

15. How much power is consumed when a transmitter transmits at power level of 30 dBm?

Answer: 30 = 10log(P_in_mw). P_in_mw = 1,000. Transmitter is transmitting at 1 W.

16. What is modulation and demodulation in digital communication? Could you explain what phase shift keying is?

Answer: Modulation is conversion of digital signals to analog electromagnetic wave taking place in the transmitter side. Demodulation is conversion of analog electromagnetic wave back to digital signals, which happens at the receiver side. Phase shift keying encodes symbols using different phases in electromagnetic wave.



17. What does CSMA/CA do before transmitting a data frame? What does it do when it detects a collision?

Answer: It listen to a channel before transmitting a data frame. Only when the channel is idle, the node begins transmitting. When a collision is detected, the transmitter backs up for a random amount of time, and retries transmission.

18. How are the carrier frequencies distributed in OFDM? Why is it possible that carrier frequencies are distributed in such a fasion?

Answer: In OFDM, carrier frequencies are distributed with 5 MHz to 10 MHz (small) band gap. This is possible because the bands are orthogonally placed to cancel out sidebands.